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INDUSTRIAL-DUST EXPLOSIONS

BY

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INDUSTRIAL-DUST EXPLOSIONS[1]

By Hylton R. Brown[2]

Advertisements and articles in technical and trade journals announce the approach of a new age, in which plastics, light metals, laminated wood, and numerous other products or byproducts will be used in the construction of automobiles, airplanes, and furniture and equipment used in our factories, offices, and homes. Undoubtedly, after the war there will be many such developments which will introduce new manufacturing methods and new hazards to challenge the safety engineer. Already we know, from experience in laboratories and pilot plants where these new products are being tested, that there will be many fire and explosion hazards to be overcome. The danger of dust explosions may be one of the principal hazards, because synthetic resins and other materials used in the plastics industry, as well as metal powders, wood dust, and other finely divided substances, are capable of forming explosive mixtures in air. Heavy losses of life and property have been caused by dust explosions in flour and feed mills, starch factories, and grain elevators, and it will be well to consider the possibilities that such losses may occur in any new industry and to provide all possible safeguards against hazards. Fortunately, we have learned something about the behavior of dust explosions and know something about the ease of ignition, limits of explosive concentration, and pressure developed. Our efforts should now be directed toward the application of this knowledge in the development of safe operating practices.

Extent of the Hazard

Examination of lists of manufacturers shows that there are in the United States approximately 28,000 plants where dust-explosion hazards may exist. At one time, only carbonaceous dusts, such as coal, grain, starch, sugar, and wood dusts, were considered capable of forming explosive mixtures with air, but recent laboratory tests have shown that many of the metal powders, such as zirconium, magnesium, aluminum, and titanium, are more hazardous than the carbonaceous dusts. Tests with samples of powdered materials used in the plastics industry indicate that many of them are only slightly less hazardous than the most explosive metal powders. The former general rule that dust-explosion hazards existed only where combustible material was produced in finely divided form must be revised to meet present conditions and to agree with the results of laboratory research. It now

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appears that the hazard exists whenever material that will burn or oxidi readily is reduced to powder form and wherever dust is produced or handl in connection with the manufacture or processing of such materials.

It has not been possible to obtain complete records of dust-explosi losses because many of the early explosions probably were reported as fires. In the past 25 years, 567 dust explosions have been reported, in which 372 persons were killed and 936 were injured. The total reported property loss exceeded $52,000,000. Last year, alone (calendar year 194 41 dust explosions were reported in which 13 persons were killed, 44 injured, and the property loss exceeded $9,000,000. These explosions occu red in metal-powder plants, grain elevators, woodworking plants, flour mills, starch factories, feed and cereal mills, cotton mills, a furfural plant, and several establishments handling miscellaneous products.

Over 1,000,000 persons are employed in plants subject to the hazard of dust explosions, and every safety engineer in such plants should give special attention to the sections of the property under his supervision in which dust ignitions may occur. Such sections usually include grindi screening, mixing, aspirating, and polishing operations as well as certa cleaning processes.

Conditions Under Which Explosions Occur

The requisites for a dust explosion are (1) a cloud of dust in suspension in air within certain limits of concentration and (2) a source o ignition of sufficient intensity to start combustion. In all industrial plants handling finely divided material, there are many possible combina tions of circumstances that may produce the conditions necessary for an explosion, and in the minds of many explosion investigators the questi is not "Why do dust explosions occur?" but "Why do we not have more dus explosions?"

Many explosions start in or around grinding machinery. The proces is essentially one that produces dust or fine particles either as the d sired product or as a byproduct, and there are numerous possible source of ignition. Foreign material, such as nails, bolts, or stones, may en the grinder with the feed and produce sparks, or the metals may be heat by friction or impact within the grinder until it reaches a temperature capable of igniting the dust.

Other dust explosions occur in bolting, sifting, or screening oper tions. Dust clouds are normally produced in such equipment, and static sparks are frequently believed or assumed to be the cause of the dust ignition.

Conveyors and conveying equipment may create dust clouds either du ing normal operation or when they are overloaded or break down. Fricti heat or sparks produced by impact of moving metallic parts may then be sponsible for dust ignitions.

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Mixing and blending operations generally produce dust clouds, and static or metallic sparks are believed to have been responsible for their ignition.

In driers or kilns, dust clouds are frequently formed during normal operation. This is particularly true of spray driers in which explosive concentrations of the fine dried material may be present at the beginning, end, or for prolonged periods of each run. The source of heat for the drier may be the source of ignition for the dust cloud.

Saws, cutters, shapers, and sanding machines may create explosive dust clouds, and there is always the possibility of ignition by sparks or heat produced in such operations.

Under certain circumstances equipment installed for the collection and removal of dust may create the conditions that may cause an explosion. Heavy concentrations of dust are sometimes handled through suction hoods and air lines, and research has established the fact that high-voltage charges of static electricity may be formed on the ducts or on the dust particles. If proper grounds are not provided, sparks produced by the accumulated charges may ignite the dust in suspension in the ducts or in the collector.

In many plants it is not possible to retain the dust within the processing and handling equipment, and, as the fine particles of combustible material become scattered through the atmosphere of the plant, explosive mixtures are formed where many sources of ignition may be present. Unprotected electric lamps and unapproved electrical equipment are possible sources of ignition under such conditions. Sparks produced by tools, shoe taps and nails, smoking, use of welding and cutting flames, heating devices, and small fires due to spontaneous heating or other causes may be responsible for the initiation of a dust explosion.

Laboratory Experiments

To develop methods of providing protection against the dust-explosion hazards previously mentioned, it was necessary to learn something about the behavior of dust and the factors affecting its inflammability or explosibility. Equipment has been developed with which it is possible to determine the ignition temperature, the relative inflammability, the ease of ignition, the limits of explosive concentration, and the pressure produced following ignition of dust clouds of different concentrations. In connection with these experiments, information has been obtained on the effect of particle size and shape, uniformity of size and distribution of the dust particles, moisture content, percentage of volatile matter and ash, and rate of oxidation.

It is not possible at this time to discuss in detail the behavior of all types of dusts in laboratory experiments. A few general statements can be made that will indicate the effect of certain factors upon the explosibility of some dusts and permit certain group classifications that will indicate the relative explosion hazards in plants handling such products.

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Carbonaceous dusts. - Coal dust can be cited as an example of the group of carbonaceous dusts that have been tested in the laboratory to determine their relative inflammability, and some of the following pertinent data for 200-mesh Pittsburgh coal dust will be of interest:

Ignition temperature of dust cloud, 610° C.
Relative inflammability, 90+.
Minimum energy required for ignition of dust cloud, 0.04 joule.
Minimum explosive concentration, 0.055 oz./cu.ft.
Maximum pressure at 0.5 oz./cu.ft., 46 lb./sq.in.
Maximum rate of pressure rise, 780 lb./sq.in./sec.

In these laboratory tests, 200-mesh material is used both in experimentation and demonstration to permit direct comparison of test results obtained with dusts of different types. Previous experiments have shown that 8-mesh material is too coarse to enter into the inflammation or explosive reaction. The 20-mesh fraction of coal dust does not ignite and propagate flame readily but appears to be capable of contributing to an explosion if it is initiated in finer dust. Flame propagation and high pressures are obtained in tests with 30- to 200-mesh dust.

More than 130 carbonaceous dusts have been tested and classified according to their explosibility. This group includes coal, virtually all of the grain dusts, such as corn, wheat, oat, barley, and rye dust, and the products of milling, such as flour, feed, meal, starch, and malt. Other examples of carbonaceous dusts tested and classified are wood flou powdered milk, spices, tobacco dust, powdered sugar, cocoa, drugs, leath dust, and certain insecticides. The maximum rate of pressure rise that indicates the severity of the explosion hazard ranges from low to high f dusts in this group. Grain dust is considered to have a low rate of pre sure rise - 200 pounds per square inch per second. Coal dust has a medi rate of pressure rise - 780 pounds per square inch per second - and corn starch has a high rate of pressure rise - 1,590 pounds per square inch p second.

Metal powders. - Magnesium powder is a good example of the group o metal powders that have been found capable of forming explosive dust clouds in air. Laboratory tests have provided some important data on t explosive properties of this powder:

Ignition temperature of dust cloud, 520° C.
Relative inflammability, 90+.
Minimum energy required for ignition of dust cloud, 0.02 joul
Minimum explosive concentration, 0.020 oz./cu.ft.
Maximum pressure at 0.5 oz./cu.ft., 72 lb./sq.in.
Maximum rate of pressure rise, 4,760 lb./sq.in./sec.

More than 50 samples of metals and alloys have been tested in the laboratory and classified according to their relative inflammability. This group includes aluminum, antimony, iron, lead, magnesium, tin, titanium, zirconium, and alloys or mixtures of these or other metals amon

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the 30 or more now available in powdered form. Ignitions and explosions of metal powders may occur under the same conditions required to produce explosions of carbonaceous dusts, and, like the first group, the maximum rate of pressure rise for the metal powders ranges from low to high. Lead powder is one of the group that presents virtually no dust-explosion hazard. Although lead dust clouds can be ignited at 580° C. and the relative inflammability is 20, the maximum pressure produced is only 2 lb./sq.in., and the maximum rate of pressure rise is only 50 lb./sq. in./sec. Tin can be classified in the group that presents a moderate or medium explosion hazard, because it produces a maximum rate of pressure rise of 850 lb./sq.in./sec. In the group that presents a high or serious explosion hazard, there are several outstanding examples - aluminum, magnesium, and zirconium. A sample of aluminum produced the highest rate of pressure rise measured in this series of tests - 5,700 lb./sq.in./sec. Zirconium is included in the particularly hazardous group because it has a maximum rate of pressure rise of 2,570 lb./sq.in./sec. and because of its ease of ignition. A number of ignitions were obtained at room temperature without any outside source of heat or flame when a quantity of the finely divided powder was blown into the air. Ignitions are believed to be due to static electricity on the dust particles.

Plastic powders. - Some of the phenolic-type resins can be used to illustrate the hazard of dust explosions in plants manufacturing or using plastics in powdered form. Laboratory tests with a sample of phenolic resin produced the following results:

Ignition temperature of dust cloud, 500° C.
Relative inflammability, 90+.
Minimum energy required for ignition of dust cloud, 0.01 joule.
Minimum explosive concentration, 0.025 oz./cu.ft.
Maximum pressure at 0.5 oz./cu.ft., 61 lb./sq.in.
Maximum rate of pressure rise, 3,160 lb./sq.in./sec.

More than 50 samples of synthetic resins and powders used in the plastic industry have been tested in the laboratory and classified according to their relative explosibility. The group includes phenolic, urea, vinyl and other types of resins and a number of molding compounds, primary ingredients, and fillers. Many of these powders were found to present a greater dust-explosion hazard than the common carbonaceous dusts. The plastic powders, like the carbonaceous and metallic dusts, can be grouped to indicate their explosibility, depending on whether the rate at which pressure is produced following ignition is low, medium, or high. Some of the resins have comparatively low rates of pressure rise (less than 500 lb./sq.in./sec.) and others, principally the urea resins, have rates of pressure rise below 1,000 lb./sq.in./sec., which permits them to be placed in the medium class. Many of the samples tested had maximum rates of pressure rise exceeding 2,000 lb./sq.in./sec. and the great majority of the powders used in the plastic industry must necessarily be considered in the high-hazard group.

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Dust-Explosion Prevention and Protection

Although many of the dusts mentioned have different explosive char acteristics, the fundamental principles for explosion prevention are es sentially the same. It is necessary to prevent, if possible, the forma tion of dust clouds and to eliminate all sources of ignition. Good housekeeping is always recommended, because it is desirable to prevent any dust accumulations where they could be thrown into suspension to fo explosive mixtures with air. Dust-collecting equipment designed and in stalled by specialists in this line of work will do much to reduce the dust-explosion hazard. An efficient system usually consists of suction hoods designed to collect the dust at points of dissemination, air line or ducts to convey the dust away from working areas by the most direct route, and filters or collectors designed to trap and remove the dust from the air. Fans or blowers are necessary to create the desired suc tion, and both the volume of air to be handled and the velocity of the air at the hoods and in the conveying lines must be controlled carefull to insure satisfactory performance of the system. Recommendations for the installation and maintenance of blower and exhaust systems can be o tained through the American Standards Association, the National Board o Fire Underwriters, and other organizations interested in safety or fire and explosion prevention. Wherever explosive dusts are handled it shou be remembered that as much of the dust-collecting system as possible should be installed outside of the building.

Several times recently, the use of flame cutting and welding equi ment has been reported as the cause of dust ignitions. The use of ope flames or heating devices capable of raising the dust to its ignition point should be prohibited wherever dust-producing machinery is in ope ation. Necessary repairs that require the use of flames or heat shou be made only when equipment is idle and all dust has been removed from the area where the work is to be done.

Special electrical equipment has been designed for dusty industri and no lights, fixtures, switches, or wiring not approved for such use should be installed where any dust-explosion hazard exists.

Any charges of static electricity detected on machinery should be removed by means of ground wires, brushes, or combs. Charges of stati electricity are particularly dangerous where sparks may ignite dust clouds.

In certain instances devices can be employed to vent or dispel th pressure built up in a dust explosion and thus prevent serious damage equipment or the building housing it. The adoption of such protective measures should not be made the excuse for neglecting well-recognized standards for preventing dust ignitions. Vents in the form of light, frangible disks on equipment, hinged windows, or panels in building walls, skylights and special ventilators may be used for protection against dust explosions, but to be effective it is necessary to maint the proper ratio between vent area and volume to be vented. Informat

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on this ratio is not available for all dusts or all types of equipment. As a general rule, 1 square foot of vent area should be provided for each 80 cubic feet of volume, if the explosion to be vented is of the type that has a low rate of pressure rise. Where the dust being produced or handled is capable of producing an explosion with a medium rate of pressure rise, the ratio should be 1 square foot of vent to 40 or 50 cubic feet of volume; and where the rate of pressure rise is high, the maximum possible venting area should be provided. It is generally possible, by providing a weak wall or roof, to obtain a venting area of 1 square foot for each 15 or 20 cubic feet of volume.

Dust-Explosion-Prevention Codes

For a number of years a committee composed of representatives of national associations interested in safety and fire and explosion prevention has been meeting at intervals to discuss dust-explosions hazards and prepare recommendations for the protection of plants where such explosions may occur. This committee, known as the Dust Explosion Hazards Committee, functions as a technical committee of the National Fire Protection Association and as a sectional committee of the American Standards Association. Through the cooperative efforts of the members of this committee and the concordant activities of laboratories and research groups, dust-explosion prevention codes have been prepared for 15 types of plants. Some of these codes contain considerable technical data on the explosive characteristics of dusts and illustrations of recommended arrangements of equipment. There is also a set of fundamental recommendations for plants that have no specific codes, and several publications of the Bureau of Mines giving the results of laboratory experiments with different groups of explosive dusts are available.

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